IMPROVEMENTS TO THE INJECTION SYSTEM OF THE KEK 2.5-GEV LINAC

S. Ohsawa, A. Asami, I. Abe, S. Anami, J.-Y. Choi, A. Enomoto, K. Furukawa, H. Hanaki, K. Kakihara, N. Kamikubota, T. Kamitani, H. Kobayashi, R. Matuda*, Y. Ogawa, T. Oogoe, I. Sato, T. Suwada, T. Takahashi#, Y. Yamazaki, and M. Yokota
KEK, National Laboratory for High Energy Physics
Oho, 1-1 Tsukuba-shi, Ibaraki-ken, 305 Japan
* Mitsubishi Heavy Industries, Co., Ltd.
Shinhama, Arai-cho, Takasago, Hyogo-ken, 676 Japan
Ishikawajima-Harima Industries, Co., Ltd.
Toyosu 3-chome Koto-ku, Tokyo, 135 Japan

Abstract

The injection system (preinjector) of the 2.5-GeV linac is now being upgraded so that intense beam acceleration can be investigated for the KEK B-factory, which is under consideration as a future project. It requires intense beams of electrons and positrons in order to achieve a practically short injection time. An outline of the improvements is given.

Introduction

An asymmetric-energy B-factory was proposed for KEK, which has intersecting rings of 3.5-GeV positrons and 8.0-GeV electrons. In order to achieve a high luminosity of over 10^{33} it is necessary to accumulate beams of more than one Ampere. Then, beams stronger than 8 x 10^8 particles per pulse are required to complete injection within one hour. This means that the e^+ beam should be increased by a factor of 5. We have recently succeeded in doubling the positron beam intensity by improving the positron focusing system.[1] In order to further increase the positron beam, it would be necessary to use a higher energy electron beam, for instance 1 GeV, by means of moving the target location downstream. The injection system to the collider rings has not yet been fixed. Some methods have been proposed: direct injection from the linac into the rings; a method using rapid cycle synchrotrons; or a combined method. In any case, a highly intense, high-energy e^- beam is necessary to produce a sufficient number of positrons.

Last summer, intense-beam acceleration was tested [2] using the 2.5- GeV linac. A beam of 17-ns, 1-A was accelerated to the exit of the linac. Instabilities were, however, observed. For the purpose of accelerating intense beams, the number of monitors was insufficient as well as the focusing strength. The linac was constructed between fiscal year 1978 and FY 1981 as an injector for the Photon Factory storage ring [3]. At the beginning, a beam of 50-mA and 1-μs was used. We then started to improve the linac from its beginning part, which includes an electron gun, a bunching system, two accelerator structures, and a beam analyzer system.

The main items improved are the following: (1) An electron gun was newly designed. The gun voltage was increased up to around 180 kV. (2) A bunching system was replaced with new one. A double prebuncher and a high-field buncher system was adopted. They are of the traveling-wave type. (3) An rf phase & power adjusting system was rearranged for the new bunching system by adding one unit. (4) The focusing system was reinforced. Solenoid coils were extended to the buncher end. (5) Some kinds of beam monitors were added: screen monitors, current monitors, and a bunch monitor. (6) An energy monochromatic system was installed near the exit of the injection system. It also functions as a bunch compressor. (7) A part of the control system was modified due to hardware changes. (8) Blocks supporting the entire system were changed to ones made of aluminium.

New system configuration

Layout of the new system is shown in Fig. 1.

Electron gun

We changed the electron gun to a newly designed one so as to be able to investigate intense beam acceleration. The gun voltage will be increased to 180 ~ 200 kV. A ceramic insulator was changed from 130 mm-long with ICF-203 flanges to one 300 mm-long with ICF-253 flanges. Three types of cathode (Y- 796,Y- 646, Y-646E) were prepared for safety.

Table 1. Electron gun design parameter changes

Gun voltage (kV)	100	--->	180,	200
Cathode type	E 3078	--->	796,	646,E
Max. current(A)	3.8	--->	10,	7
Perviance (μA/V$^{3/2}$)	0.12	--->	0.13,	0.08
N. emittance (π mm-mr)	17	--->	14,	5.5

Gun pulser

A gun pulser was modified so that maximum voltage became 200 kV. The changed elements are listed in table 2 as well as associated parameters.

Table 2. Gun pulser parameter changes

Maximum voltage	160 kV	---> 200 kV
Pulse duration	3 µs	---> 3 µs
Thyratron	ITT 8789	---> F-175
Pulse forming network		
condenser	18 nF	---> 14.6 nF
section number	3 x 4	---> 3 x 5
Pulse transformer		
step up ratio	1 : 9.56	---> 1 :12
sec. impedance	1.14 kΩ	---> 1 .8 kΩ
Load resistance (kΩ)	9.2/9	---> 8.2x2/9

Bunching system

The bunching system comprises $2\pi/3$ mode cavities of 2856 MHz. They are all of the traveling-wave type. A double prebuncher system was adopted in order to obtain short bunches and a high bunching efficiency. Prebuncher cavities were designed so that the shunt impedances are low in order to decrease the wake-field effects. In the second prebuncher, electrons loosely bunched by the first prebuncher will be accelerated at different phases, so that they will be bunched furthermore due to energy differences at a higher average energy. The role of the second prebuncher will become more important as the beam intensity becomes higher. The electrons bunched by the prebunchers are finally bunched by a buncher with a high field and are then accelerated rapidly so that they will not debunch.

Table 3. Bunching system design values

Prebuncher 1		
maximum field		0.4 MV/m
shunt impedance		15.96 MΩ/m
attenuation coefficient		0.0643 Neper/m
available input power		100 kW
cavity number		7
cavity size	D	24.318 mm
	2a	35.74 mm
	2b	89.418
Drift space		158.71 mm
Prebuncher 2		
maximum field		1.0 MV/m
shunt impedance		14.97 MΩ/m
attenuation coefficient		0.0597 Neper/m
available input power		1 MW
cavity number		5
cavity size	D	24.318 mm
	2a	36.89 mm
	2b	90.075 mm
Drift space		42.27mm
Buncher		
field strength		~15 MV/m
available input power		13 MW
cavity number		
buncher section		5
normal section		30
cavity size	D	27.01 ~ 34.99 mm
	2a	22.44 ~ 19.32 mm
	2b	83.057~81.735mm

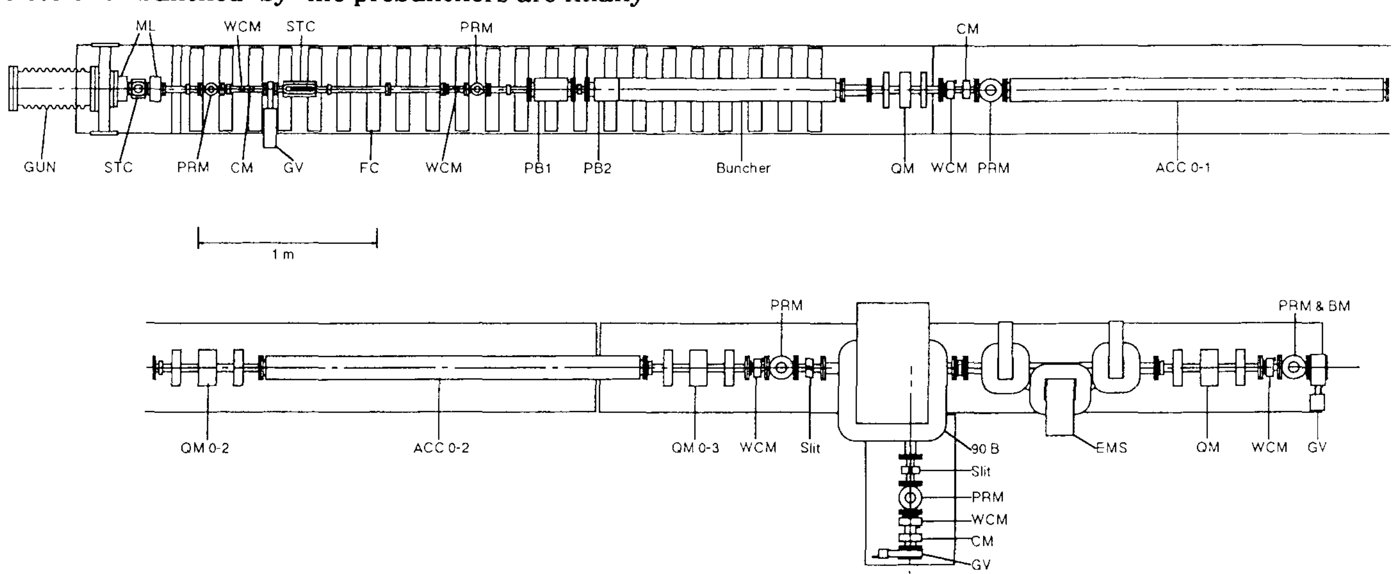

Fig. 1 Layout of the new injection system of the KEK 2.5-GeV linac. GUN is an electron gun; STC, steering coils; ML, a magnetic lens; PRM, a profile monitor; WCM, a wall current monitor; CM, core monitor;GV, a gate valve; FC, a focusing coil; PB1, first prebuncher; PB2, second prebuncher; Buncher, a buncher with accelerating cavities; QM, quadrupole magnets; ACC, accelerating cavities; 90-B, a bending magnet; EMS, an energy monochromatic system; and BM, a bunch monitor.

RF adjusting system

It is necessary to optimize the power levels and phases of microwaves input into the prebunchers and the buncher. We employed equipment which is capable of changing the power level and the phase independently [4]. This equipment has noticeable features: (1) The power divide ratio can, in principle, be changed continuously without a phase shift. This function acts as an attenuator with no phase shift. (2) It can also be used as a phase shifter.

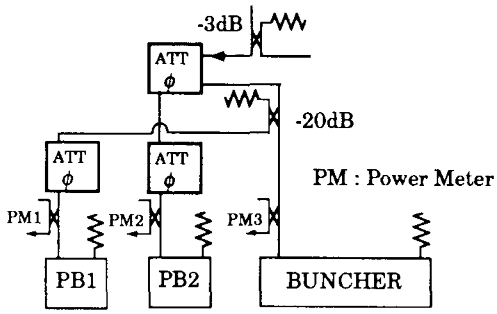

Fig. 2 Relationship between the rf phase & power adjusting system and the bunching system.

Focusing system

The focusing system has been strengthened for intense beams: Solenoid coils installed at regular intervals (165 mm) have been extended to the buncher end. The maximum field is 1 kGauss. Every two of the coils are fed by one power supply. The number of quadrupole magnets were increased from 3 to 4, and set at about the same spaces. If the focusing system is strengthened in only the injection system, it would be insufficient for intense beams.

Table 4. Magnets of the transport system

Solenoid coil	22
Set of quadrupole magnets	4
Set of steering coils	5
Bending magnet	1

Monitors

As the beam intensity increases, it becomes more important to transport beams at the centers of accelerating cavities in order to reduce any transverse wake-field effects. We added screen monitors along the linac. A bunch monitor was also established, since it is preferable for this monitor to be installed near the bunching system. A streak camera is used to analyze any transition light emitted from a metal foil, which is in a chamber of the last screen monitor on the beam line. Some investigations will be necessary. The number of rf monitors were also increased.

Table 5. Number of monitors

Profile monitor	6
Bunch monitor	1
Wall current monitor	6
Core monitor	2
Rf monitor	
Bethe hole coupler	14
phase detector	1
power meter	5

Energy monochromatic system

This system was proposed in order to compensate for energy differences produced by a beam-loading effect [5]. If there are any energy differences between bunches, after they pass the system comprising three bending magnets, the spacings between bunches would change slightly due to pass differences in proportion to the energy differences in the first approximation. If the lower-energy bunches are accelerated at phases near to the crest, the energy differences would be decreased. This system can be used as a bunch compressor. It is, however, a necessarily condition that each bunch becomes sufficiently short.

Control system

Due to the upgrade of the injection system, the number of elements to be controlled considerably increase: the DC power supplies of the focusing system, many kinds of monitors, and the rf adjusting system. It is necessary to either modify or develop much software.

Summary

Reconstruction of the injection system of the KEK 2.5-GeV linac is now in progress. Normal operation is scheduled to start on September 28. Although there is much work to do, we are proceeding with the program as prearranged. After the upgrade, investigations of intense beam acceleration will start again.

References

[1] A. Enomoto et al. "Performance of the Upgraded Positron Generator at KEK", in Proc. of the Third European Particle Acc. Conf., 1992.

[2] Y. Ogawa et al. "Experimental Investigations of a Transverse Wake-Field Instability at the KEK Electron Linac", submitted to HEAC 92

[3] J. Tanaka "Operation of the KEK 2.5GeV Linac", in Proc. of the 1984 Linear Acc. Conf., Darmstadt

[4] S. Ohsawa et al. " High-Power HybridAttenuator & Phase-Shifter Systems" 1990 Linear Acc. Conf.

[5] I. Sato, private communication